

Kentucky Agricultural Experiment Station

University of Kentucky

THE STRAWBERRY CROWN BORER *Tyloderma fragariae* (Riley)

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THE STRAWBERRY CROWN BORER

Tyloderma fragariae (Riley)

P. O. RITCHER¹

INTRODUCTION

For the past forty years, the strawberry crown borer has been the worst insect pest with which Kentucky berry growers have had to contend. The most serious outbreaks have occurred in western Kentucky, in McCracken, Warren, Ohio, and Caldwell counties. In McCracken county alone it is estimated that crown borer caused \$100,000 damage during the single season of 1936. Many strawberry patches were entirely wiped out and others had greatly reduced yields. Patches injured by crown borer were found in 24 counties of the state² (See map, figure 1). At present, the worst infestation

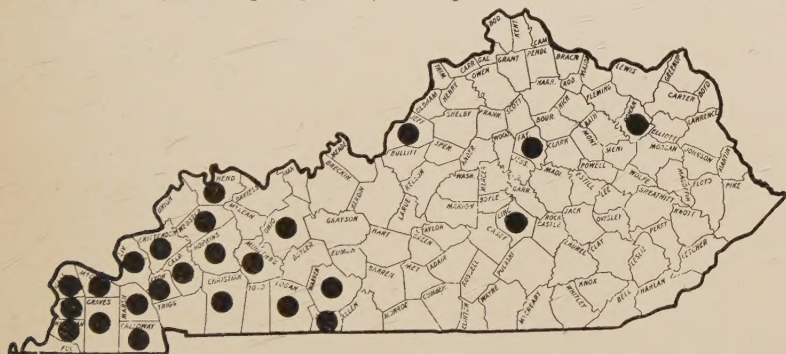


FIGURE 1. Counties in which strawberry plantings were found infested by crown borer are marked with black circles.

is centered about Kevil, in McCracken county. With the organization of new berry associations among farmers of other counties, further trouble with crown borer may be expected.

In the fall of 1936, at the request of western Kentucky strawberry growers, the Kentucky Agricultural Experiment Station initiated a project on crown borer in western Kentucky. The writer

¹ The writer wishes to express his appreciation to Professor W. A. Price for inspiration and many valuable suggestions thruout the course of this project.

² Records for certain counties are taken from the files of H. Tilson, Nursery Inspector.

was stationed at the Princeton Experiment Substation from early February to late August, 1937. This report is the result of an intensive study of the strawberry crown borer in McCracken, Ballard, Caldwell, Lyon, and Fayette counties, made during 1937 and 1938. It also includes several records made by H. Garman in previous years.

HOST PLANTS

Cultivated Hosts. The strawberry plant is the only cultivated host in which *Tyloderma fragariae* breeds. Considering Kentucky as a whole, the important commercial varieties of berries are Aroma, Blakemore, Dorset, Premier, and Gandy. All of these varieties have been found heavily infested with crown borer.

It is common knowledge that the Aroma variety, so extensively grown in western Kentucky, produces runners and plants sparingly under dry conditions. This was very evident during the dry season of 1936. To find out whether prolific varieties such as Blakemore and Dorset stand up better under heavy infestations of crown borer, varietal plots, replicated five times, were maintained at Princeton during 1937. On August 11, these showed little difference in resistance among the mother plants of the three varieties and little difference in the number of runner plants established under conditions of equally severe crown borer attack (See table 1).

Wild Hosts. The crown borer was found breeding in the wild strawberry and in one species of cinquefoil, or five finger as it is commonly called (figure 2). In many strawberry patches in western

Table 1. Effect of crown borer on three varieties of strawberry, at Princeton, 1937.

Variety	Aroma	Blakemore	Dorset
Infested mother plants, total for 5 plots	162	163	148
Runners put out	399	317	320
Average per mother plant	2.5	1.9	2.2
Runner plants established	255	264	217
Average per mother plant	1.6	1.6	1.5
Runner plants infested	7	1	4
Uninfested mother plants, 5 plots	20	15	24
Runners put out	75	50	89
Average per mother plant	3.8	3.3	3.7
Runner plants established	59	37	80
Average per mother plant	3.0	2.5	3.3

Kentucky the infestation is traceable to adult crown borers which migrated from nearby cinquefoil. At the S. C. Magruder farm, in 1937, great care was taken in digging and cleaning plants for three new patches which were set at least 500 yards from the nearest old patches. In spite of all this crown borer invaded the patches by midsummer. Examination showed that every berry patch was bordered by cinquefoil heavily infested with crown borer.

Three species of cinquefoil, or five finger, were found growing in western Kentucky. These are *Potentilla monspeliensis*, *P. recta*, and *P. canadensis*.³ *P. monspeliensis* is a rare species in that area and was not found infested. *P. recta* was common on one farm near Princeton, Kentucky, but was not found elsewhere. Altho growing alongside strawberry patches, none of this species was infested. The third species, *P. canadensis* or common cinquefoil, abounds all over the western two-thirds of the state and usually was found heavily infested with the strawberry crown borer. A summary of the crown borer infestation found in common cinquefoil in several localities in western Kentucky is given in table 2. If the crown of a plant contained a borer larva or a fresh burrow it was counted infested. Old injuries were not counted.



FIGURE 2. Common cinquefoil, *Potentilla canadensis* L., attacked by crown borer.

³ Identifications made by Mary Didlake of the Department of Entomology and Botany.

Common cinquefoil was found infested with crown borers in several widely scattered localities at considerable distances from places where cultivated strawberries were grown. It appears from this that the strawberry crown borer is a native to Kentucky and occurred here before cultivated strawberries were introduced. *P. canadensis* grows along roadsides, in neglected fence rows, along woods edges, in woodlands, along railroad rights of way, along the sides of ditches, in waste land and in neglected fields. It does not grow in cultivated fields. It is widespread and may be found on nearly every farm in McCracken county.

The wild strawberry, *Fragaria virginiana* Duchesne, is also a native wild host of the crown borer but does not occur as abundantly as in earlier days. Infested plants were found in Lyon and Caldwell counties. Wild strawberries are scarce in the Paducah berry area but do occur on a few farms.

Table 2. Infestation of common cinquefoil plants by the strawberry crown borer, Western Kentucky, 1937.

Locality	County	Situation	Date	No. examined	No. in- fested	No. in- fested	% in- fested
Princeton	Caldwell	Waste land	6/12	25	9	16	64
Princeton	Caldwell	Along railroad	6/25	41	36	5	12
Princeton	Caldwell	Waste land	7/16	44	7	37	84
Six miles west of Princeton	Lyon	Waste land	6/15	50	38	12	24
Between rivers	Lyon	Roadside	7/21	74	66	8	11
Kevil	Ballard	Waste land	8/5	61	43	18	29
Kevil	McCracken	Roadside	6/16	29	19	10	34
Kevil	McCracken	Fence row	6/16	31	21	10	32
Kevil	McCracken	Woods edge	6/16	13	10	3	23
Kevil	McCracken	Roadside	6/16	24	14	10	41
Kevil	McCracken	Roadside	6/16	23	15	8	35
Kevil	McCracken	Roadside	7/2	35	18	17	48
Kevil	McCracken	In woods	7/21	13	2	11	85
Kevil	McCracken	In ditch	7/21	51	13	38	74
Metropolis Lake	McCracken	Roadside	7/1	76	57	19	25
TOTALS				590	368	222	37.6

LIFE CYCLE

Investigators in other states have reported that the crown borer has a single generation a year. In 1937, the writer found a small second generation of crown borer as a result of his studies in west-

ern Kentucky. In 1938, however, no evidence of a second generation was obtained.

The great majority of crown borers pass the winter as adults under trash or in the soil of infested patches. A very few pass the winter within infested plants and mature in February and March. During the warm days in February and March overwintering beetles are active and feed on strawberry foliage.

Egg laying by the overwintering beetles begins early in March and continues thru August. First-generation larvae begin to hatch in April and may be found as late as October tunnelling thru strawberry crowns. Pupation of first-generation larvae begins the middle of June or shortly thereafter. First-generation adult crown borers begin emerging the third week in June and continue to emerge thru October. The majority of the new-generation adults emerge in July and August.

In 1937, some of the earliest first-generation adults began laying eggs late in July and continued to do so into September. These eggs gave rise to second-generation larvae part of which at least became adult crown borers the same fall and left the berry crowns. Crown borer adults feed on strawberry foliage in the fall and on warm days a few are found feeding in December and January.

STAGES

The Adult. The adult crown borer is a small, brown, snout beetle slightly less than one-fifth of an inch long, shaped like a grape seed (figures 3 and 4). Each wing cover is marked with three black bars. The hind wings are dwarfed and not functional so that the adult crown borer must depend upon its legs for locomotion. It may be carried from place to place by water or by the grower.

The adult is seldom seen by the berry grower because of its retiring habits and the way its colors blend with those of the soil. While feeding on the leaves, adults always cling to the under surface. Upon the slightest disturbance the beetles fall down among the soil litter and "play 'possum."

Male crown borers are usually shorter and narrower than the females but this is not always the case. In establishing egg cages for rearing work the only safe way to select males and females is to

choose beetles falling in the extreme size groups. Individuals 1.8 mm or less wide and 4.1 mm or more long are almost always males and individuals wider than 2.1 mm, regardless of length, are usually females. In rearing work, it is not safe to use pairs attempting to

mate since males often attempt to mate with other males. There appear to be no differences in external characters other than size by which the sexes can be separated.

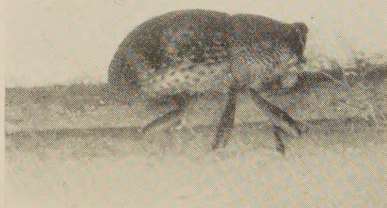


FIGURE 3. Adult strawberry crown borer.

Males range from 3.4 mm to 4.7 mm in length and 1.6 mm to 2.1 mm in width. Females range from 3.6 mm to 5.0 mm in length and 1.5 mm to 2.4 mm in width. Sixty-

five males averaged 4.18 mm in length and 1.87 in width. Sixty-one females averaged 4.3 mm in length and 1.97 mm in width.

The Egg. The egg is oval and of a light yellow color (figure 4). Upon drying it takes on a chalky, white appearance. Based on measurements of 20 eggs, the egg averages about 1 mm in length and .65 mm in width. There are no conspicuous markings on the glistening chorion. The egg is usually more or less covered with a coating of a whitish material, probably a secretion of the female, which gives it a whitish appearance when dried.

The Larva. The newly hatched larva is a very small grub which has a light yellow body and a light brown head. Its mandibles are dark brown. The head of the newly hatched larva appears too large for the body. The body, two-thirds of its distance behind the head, tapers abruptly to a blunt point. With the beginning of feeding on the tissues of the strawberry plant, the larva takes on a pinkish hue.

The larva's growth is slow and often a month or more is required for the completion of the larval stage. As it grows it moults four times making five instars thru which it passes before pupating. The duration of the first instar ranged from 7 to 11 days for 8 larvae. That of the second was 8 and 10 days for two larvae. The duration of the other instars was not observed. The sizes of the head cap-

sules for the various instars are given in table 3. After the larva becomes full grown it stops feeding, lies outstretched in its burrow, and its body takes on a whitish color. It is then said to be in the prepupal stage which lasts 3 to 4 days (figure 4).

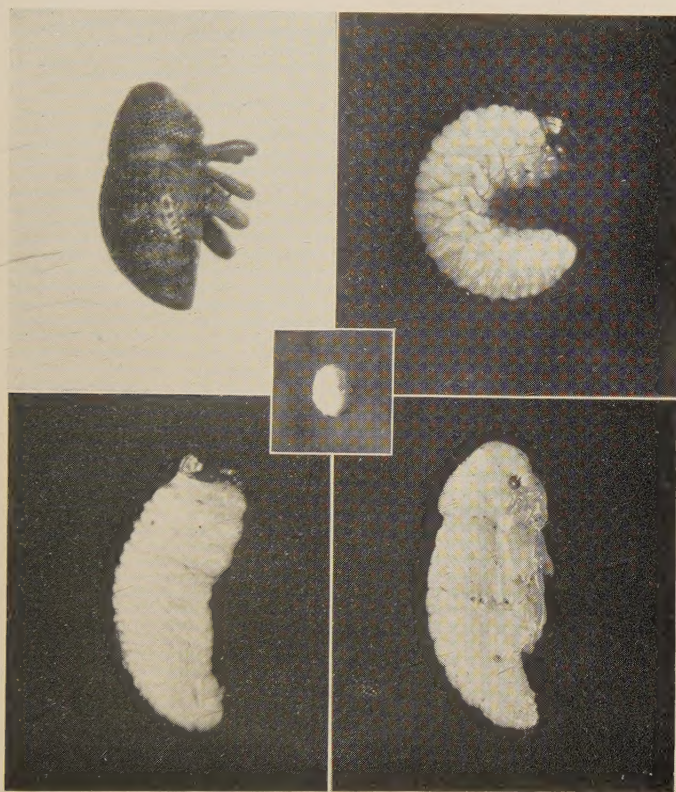


FIGURE 4. Adult, larva, egg, prepupa, and pupa of the strawberry crown borer, *Tyloderma fragariae* (Riley). All enlarged seven times natural size.

The Pupa. This is the stage between the larva and the adult beetle. During this stage no feeding is done. At first, the pupa is pure white. By the third day after pupation, the eyes begin to darken (figure 4). About the sixth day, the mandibles show dark and the ends of the tibia become light brown. In three or more days the adult beetle emerges.

LIFE HISTORY STUDIES

Life history studies of the strawberry crown borer were made by general observations in the commercial berry areas of western Kentucky, by the use of test plots and caged plants, and by the maintenance of isolated pairs of crown borers in an insectary. Much of the rearing work was done in 1937 at the western Kentucky substation, at Princeton. Other rearing work was carried on at Lexington in 1937 and 1938.

Table 3. Width of head capsules of crown borer larvae.

Instar	Number measured	Minimum	Maximum	Average
		mm.	mm.	mm.
First	27	.435	.49	.456
Second	8	.61	.687	.626
Third	6	.73	.86	.81
Fourth	4	.95	.986	.966
Fifth	7	1.01	1.09	1.05

Overwintering Stages. The majority of crown borers overwinter in the adult stage. During February, many beetles were found in berry patches, lying on the surface of the soil under or in the surface litter, close to the bases of strawberry plants. A few adults were found below the general surface of the soil, concealed in double strawberry crowns. Other beetles were found hibernating in the soil.

It is commonly stated that the crown borer passes the winter only in the adult stage. While this is true in the majority of cases, evidence was secured in 1937 in western Kentucky showing that, in some years at least, a small percent of the crown borers pass the winter in other than the adult stage. As summarized in table 4, one live pupa was cut from an infested crown February 15, and 4 newly transformed adults were cut from plants between March 11 and April 1. This same phenomenon is mentioned by Forbes (1883) and Baerg (1936).

Spring Activity and Feeding. Field observations were begun February 11, 1937, in a heavily borer-infested, two-year-old, Aroma patch on the Experiment Substation grounds at Princeton. On this date there were already signs of rather recent adult crown borer

feeding on strawberry leaves. There was some adult activity and feeding on foliage on February 15, a day on which the temperature reached 61° F. One male, upon dissection, was found to contain green, leafy material in its alimentary canal and several fresh feeding holes were found in berry leaves. On the remaining days of February no adults were found feeding because of the prevailing low temperatures.

Table 4. Evidence indicating that some crown borers winter in other than the adult stage. 1937.

Locality	Date	Number of injured plants	Number of pupae found	Number of recently transformed adults
Princeton	Feb. 15	49	1	0
Princeton	March 3	31	0	1
Paducah	March 11	—	0	1
Paducah	March 19	58	0	1
Paducah	April 1	53	0	1

With the warmer days of early March many crown borer adults became active in infested patches at Paducah and Princeton and were often found in the act of feeding on the under surfaces of strawberry leaves. No adult was ever observed feeding on the upper leaf surface. In March, the best way to find adult crown borers was first to look for fresh leaf injury. The adult was usually to be found in the act of feeding or "playing 'possum" beneath the leaf.

Adult crown borer injury to foliage was most conspicuous from March 2 thru the middle of April. With the beginning of the active egg-laying period and higher temperatures, fresh feeding holes on exposed leaf surfaces were found only infrequently. It is concluded from a study of daily temperatures and feeding records that little crown-borer feeding occurs on days when the maximum temperature is below 60° F. (figure 5). Below 51° adults are entirely inactive.

Types of Adult Feeding. The feeding of adult crown borers on strawberry leaves is always done from the lower surface. The feeding holes are irregular in shape and cut thru the leaf (figure 6). Adult feeding is not confined to the leaf surfaces. Feeding on the stipules of the leaves is very common. The injury consists of irregular holes eaten thru the stipules and often there is feeding on the

stipular margins. Adults also feed on the stems of the leaves, on the lateral roots, and on the sides of the crowns.

Mating. Mating was first observed in the field on March 2, 1937, at Princeton. The pair under observation was out in the open clinging to a dead grass stem. At this time, 2:15 p. m., the air temperature was 62° F. Copulation was observed frequently after March 2 when the temperature was high enough. Mating occurred in such situations as on a dead leaf sheltered by a green leaf, on the under surfaces of leaves while the female was feeding, on trash close to the berry plants, and on the soil surface.

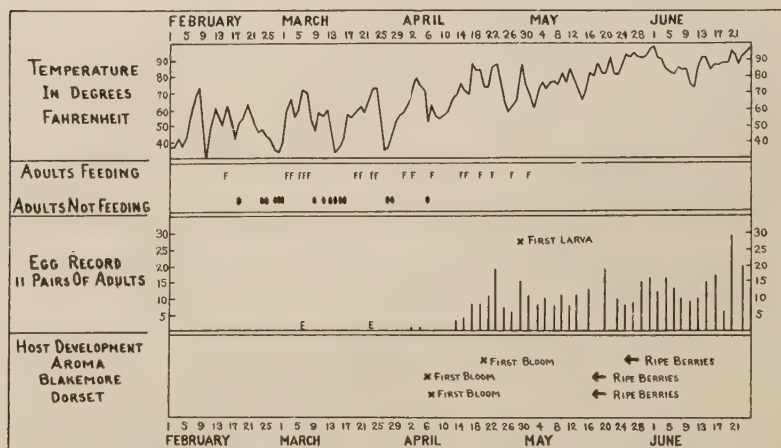


FIGURE 5. A graphic summary of records correlated with the spring activity of the strawberry crown borer in 1937.

Egg Laying. A good deal of attention was given to the study of oviposition since many phases of this subject are of direct importance in formulating control measures for crown borer. Some of the questions which the writer tried to answer were, when are the first eggs laid, over what period of time are eggs laid, how many eggs are laid by a single crown borer, and what is the most reliable way to forecast the dead-line for digging infested plants that are certain to contain no eggs.

Four methods were used to determine when the first eggs were laid. By the first, adults were collected at intervals from heavily

infested berry patches and dissected to check on the egg development. It was found that egg development in the ovaries could be divided roughly into four stages, no development, slight development, some development, and fully developed.



FIGURE 6. Strawberry plant showing typical feeding holes of crown-borer adults on leaves.

At Princeton, one female was found containing two fully developed eggs, February 23, 1937. No other females with fully developed eggs were found at Princeton until March 8, 1937. At Paducah, the first females containing fully developed eggs were found March 18, 1937. In 1938, females with fully developed eggs

were found at Paducah and Princeton on March 10 and 11, respectively. The first female containing fully developed eggs at Lexington was found March 19 (see table 5).

Table 5. Egg development of the strawberry crown borer, observed by dissecting females.

Date	Number of females dissected	Degree of development			
		None	Slight	Some	Full
1937		At Paducah			
March 6	10	4	6	0	0
March 11	11	4	6	1	0
March 15	6	2	3	1	0
March 18	20	6	7	3	4
March 25	11	2	2	2	5
April 3	10	1	2	4	3
		At Princeton			
Feb. 15	2	2	0	0	0
Feb. 22-23	10	7	2	0	1
March 8	18	6	5	5	2
March 19-20	10	0	3	2	5
April 24	8	2	1	0	5
		At Lexington			
Dec. 24	4	2	2	0	0
1938					
Feb. 11	3	3	0	0	0
Feb. 14	4	2	2	0	0
March 15	6	0	5	1	0
March 19	4	0	1	2	1

The second method used to determine when the first eggs were laid, was to isolate individual pairs of adults in jelly-glass egg cages. These were kept in an outdoor insectary and supplied at intervals with a fresh, well cleaned berry plant. These berry plants were examined for crown borer eggs at two-day intervals. Using this method, in 1937, eggs were laid at Princeton March 8 and at Paducah March 24. In 1938, eggs were laid at Lexington March 21. No rearing was done in western Kentucky in 1938.

The third method consisted in digging berry plants from heavily borer infested patches at about weekly intervals, beginning in February. Such plants were immediately cleaned and washed to free

them of all adult crown borers. They were then heeled-in in a borer-free location. Later, when crown borer larvae were common in the field and easy to find, all of the plants from the weekly diggings were cut open. The presence of larvae in a given series of plants was taken as proof that eggs were laid before the time that particular group of plants was dug.

In 1937, one plant out of 73 dug at Princeton, March 20, was infested, showing that eggs were laid before that date. None of the plants dug at Paducah on March 31, 1937, or earlier were later found infested (table 6). In 1938, no infested plants were found

Table 6. First oviposition by the crown borer as indicated by examination of plants dug weekly, at Princeton and Paducah, in 1937.

When dug	When examined	Number examined	Number infested	Percent infested
Princeton				
Feb. 27	May 29	100	0	0
Mar. 6	May 31	101	0	0
Mar. 13	June 1	79	0	0
Mar. 20	June 4	73	1	1.4
Mar. 30	June 3	94	0	0
Apr. 7	May 28	69	7	9.6
Paducah				
Mar. 11	May 31	82	0	0
Mar. 17	June 4	75	0	0
Mar. 24	June 3	92	0	0
Mar. 31	May 28	79	0	0
Apr. 10	May 28	107	14	13.1

among the plants sent from Princeton, February 22 and March 11. No infested plants were found among 20 plants dug March 21 at Lexington, on which adult beetles had recently fed.

The fourth way of determining when the first eggs were laid was to search for eggs or newly hatched larvae in plants from heavily infested patches. This proved to be a laborious undertaking as far as the first eggs were concerned. The finding of the first newly hatched larvae enabled the writer to approximate the time at which the first eggs were laid since the length of the egg stage was known quite exactly. From the dates on which the first borer larvae were found in 1938, it seems probable that several eggs were laid before March 13 at Paducah and before March 14 at Princeton.

It is concluded from the data obtained by the methods outlined,

that no crown borer eggs are laid in the vicinities of Princeton and Paducah until early in March. In 1938, in spite of unusually warm weather in February, no evidence was secured at Paducah, Princeton, or Lexington that any crown borer eggs were laid earlier than March 10.

It is concluded from a study of temperatures and crown borer activity in the field that there is no danger of eggs being laid in the spring until the air temperature reaches 68° F. for at least two days in succession (figure 5).

It is also concluded that the simplest way to secure accurate data on the time the first crown borer eggs will be laid is to follow the egg development of a sufficient number of females by dissection and correlate this with the prevailing temperatures.

Egg-laying Period. In 1937, at Princeton and Paducah, overwintering adults laid eggs from March until September. In 1938, four out of five overwintering females from Princeton, taken in the field in the middle of June, laid eggs thru part of August. A summary of egg laying under insectary conditions in 1937 and 1938 is given in tables 7 and 8. As will be seen from table 7, one female of 11 pairs isolated in 1937, began laying April 3 and did not finish laying until August 31.

According to Marcovitch (1923), adult crown borers are very long lived and some were observed to lay eggs a second year. The pairs of adults for which figures on 1937 egg production are given in table 7 were placed with potted berry plants in a screened insectary for overwintering at Lexington. Most of these adults lived over the winter and 7 females laid one or more eggs during 1938. Data on the eggs laid this second season are also given in table 7. In 1937, three early, first-generation adults laid a few eggs, between July 26 and September 13. No second-generation eggs were found in 1938.

Based on observations in the field and insectary, crown-borer eggs are not laid in numbers, in western Kentucky, until the middle of April. May, June, and July are the months in which egg laying is the heaviest.

Where and How Eggs Are Laid. The eggs are always laid in the strawberry plant (figure 7). They are usually deposited in

Table 7. Number of eggs laid by individual strawberry crown borers in an insectary and period of oviposition, 1937 and 1938.

Pair	B	C	D	E	F	G	H	I	J	M	N	Totals
1937												
March	0	0	0	0	0	0	0	0	0	0	0	0
April	7	0	5	14	8	5	8	8	9	6	4	74
May	12	6	13	13	11	20	9	12	18	15	9	138
June	4	17	21	26	23	23	20	26	23	18	16	217
July	15	17	22	25	21	19	23	27	21	12	0	202
August	0	2	6	24	8	8	7	3	1	0	0	59
Subtotals	38	42	67	102	71	75	67	76	72	51	29	690
First egg	April 14	May 2	April 16	April 3	April 18	April 14	April 16	April 22	April 16	April 18	April 20	April 3
Last egg	July 16	Aug. 9	Aug. 7	Aug. 31	Aug. 19	Aug. 17	Aug. 11	Aug. 5	Aug. 1	July 26	June 24	Aug. 19
1938												
March	0	4	0	0	1	0	0	1	0	0	0	6
April	1	9	10	7	7	0	11	2	0	0	0	47
May	0	0	6	4	7	0	10	3	0	0	0	30
June	0	0	0	9	6	0	0	0	0	0	0	15
July	0	0	0	17	3	0	0	2	0	0	0	22
August	0	0	0	3	0	0	0	0	0	0	0	3
Subtotals	1	13	16	40	24	0	21	8	0	0	0	123
First egg	April 29	Mar. 21	April 6	April 15	Mar. 30		April 1	Mar. 28				Mar. 21
Last egg	April 29	April 22	May 18	Aug. 6	July 15		Aug. 6	July 20				Apr. 29
Total for 2 years	39	55	83	142	95	75	88	84	72	51	29	813

shallow excavations and covered with dirt and bits of tissue gnawed by the female from nearby areas. The excavations are made near the origin of lateral roots and close to the surface of the soil. They often cut thru the stipular areas of several old leaf bases and may or may not penetrate the crown proper.

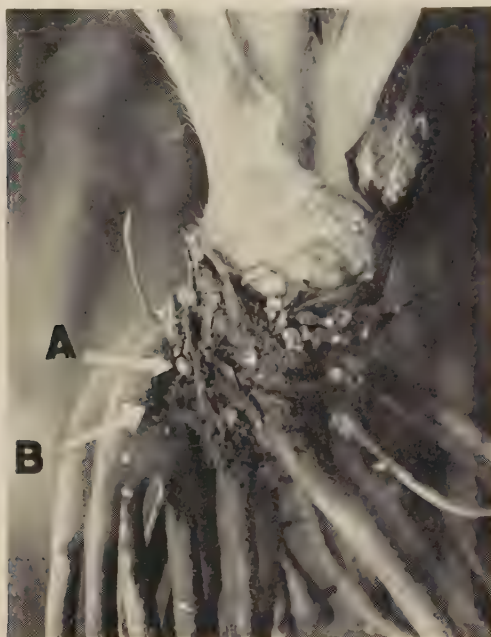


FIGURE 7. A, Crown borer egg laid in excavation in berry plant at base of lateral root; uncovered to show egg. B, Location of a second borer egg which was not uncovered.

Some eggs are merely tucked in behind the dead tissue of the old leaf bases with no special excavation apparent; others are deposited in the crown itself below the origin of the uppermost lateral roots and below the surface of the soil. A few are laid in excavations in the lateral roots, usually rather close to their points of origin.

The following extracts from notes describe typical places of egg deposition in more detail:

April 5, 1937. "One egg deposited inside crown. The egg cavity passes thru an old dried stipule close to its leaf base and penetrates the crown

beneath for a distance of about 0.3 mm. Pulling back the old leaf base reveals the egg inserted in the hole in the crown."

April 27, 1937. "One egg found deposited under dead leaf scales. Egg lying in shallow excavation made in back of midrib of old leaf toward its base. This egg would have been removed in cleaning plant."

April 27, 1937. "One egg laid in shallow cavity in crown at the juncture of the crown and a lateral root. The egg is covered with bits of tissue part of which was chewed from the surface of the lateral root."

April 20, 1937. "One egg found in shallow excavation down on crown just above base of lateral root. This lateral root is located below three other lateral roots. This location is about $\frac{3}{4}$ inch below the surface of the soil. The egg lies in the excavation about half its width. It is covered with bits of tissue and dirt. The location of this egg is concealed by the dead, scale-like tissue, probably of old leaf bases."

April 20, 1937. "One egg laid in excavation in base of lateral root and covered with bits of tissue. This lateral root is near the top of the crown and is just at the surface of the soil."

The length of time required for the laying of a crown borer egg was not determined altho parts of the process were observed. According to Marcovitch (1923) about 100 minutes was required for one female to excavate the egg cavity, deposit and cover the egg.

In excavating the egg cavity the female stands astride the plant with her head down and the main axis of her body parallel with that of the plant. After depositing the egg one female was observed to cover it by biting off bits of tissue from the bases of the nearby lateral roots. She tamped each bit of tissue over the egg with up and down movements of her head and rostrum, moving her antennae nervously during the process.

Number of Eggs Laid. The number of eggs laid by female crown borers kept under observation in the insectary for the season of 1937, ranged from 29 to 102 with an average number of 62.7 (table 7). Seven of the females under observation in 1937 laid

Table 8. Oviposition by the crown borer under insectary conditions, Lexington, 1938.

Pair Number	Was laying	Finished laying	Number of eggs		
			June	July	August
38-6A	June 13	August 15	12	31	7
38-6B	June 13	August 19	12	12	5
38-6C	June 13	August 15	17	47	12
38-6D	June 13	August 15	10	29	13
38-6E	June 22	July 11	2	2	

eggs a second season (1938). The number laid ranged from 1 to 40 with an average of 17.5 per female. The maximum number of eggs laid during the two seasons by a single female was 142. The maximum number of eggs laid in one day by one overwintering female was 3. About one egg a day is the usual number.

Duration of Egg Stage. Crown borer eggs laid early in the spring are very slow in hatching. Eggs laid during April, 1937, for example, required 20 to 27 days to hatch. During June, July, and August the incubation period was greatly shortened and averaged about 10 to 12 days (table 9).

Table 9. Duration of the egg stage.

Number of eggs	Month laid	Maximum number of days	Minimum number of days	Average number of days
At Princeton, 1937				
17	April	27	20	24.1
34	May	18	9	13.1
49	June	13	9	11.3
60	July	13	8	10.2
At Lexington, 1938				
2	March	34	32	33
2	April	26	26	26
5	May	21	14	17
8	June	15	11	12
7	July	11	10	10.4

The Larval Stage. The larva of the strawberry crown borer is a legless grub with a whitish, curved body and a light brown head. The larva spends practically all its life within the strawberry crown where it makes a dark, winding tunnel thru the crown, feeding as it goes.

The hatching crown larva makes its escape from the egg shell thru a ragged hole toward one end of the egg. The empty shell is not eaten by the larva. Some newly hatched larvae enter the crown directly from the point at which they hatch. Others tunnel down thru the leaf base in which the egg was laid until they reach the crown. Often small larvae burrow thru the region of the cambium layer in a horizontal plane, half girdling the plant before they tunnel into the inner part of the crown.

During the course of its growth the crown borer larva makes its characteristic, dark, frass-filled burrow (figure 8). Especially in a smaller, one-year plant, a larva may tunnel to the bottom of the crown, then work back to a point at the top of the crown where it chews out a pupal cavity in the bases of the green leaves. Such plants die back very quickly.

Usually a single larva matures in a plant but often as many as three may mature. As many as six larvae have been found in a single plant in the field. Plants with multiple crowns most often support several larvae.

The larva of the crown borer develops slowly. The length of the larval stage was 43, 34, and 37 days for 3 larvae hatched from eggs laid April 13, April 15, and April 21, 1937, respectively. The length of the larval stage in midsummer is approximately 20 days.



FIGURE 8. Strawberry crown cut open to show crown borer and its injury.

Effect of Crown Borer. Strawberry plants infested with crown borer are often killed or severely stunted. Those plants surviving produce fewer runners and set fewer plants. Plants are hurt worst when attacked early. When attacked in dry years, as in 1936, entire fields are often wiped out. One-year-old patches, heavily infested with crown borer, have only a partial stand of plants. Even tho most of the runner plants are uninfested, a light crop of berries the next year is the result. By the second year such a patch is usually so full of crown borer and the crop of berries so poor that it is not worth picking.

In 1937, a rather favorable year for strawberries, a survey on August 10 of 162 infested mother Aroma plants from varietal test plots gave the following results: ninety of the 162 mother plants, or 55½ percent, were killed outright or were badly stunted between late June and early August. Fifty-nine of the 90 ruined mother

plants, or 36 percent of the total number of infested plants, set no runner plants. Seventy-two infested mother plants, or 44 percent of the 162 infested, showed only slight effects of crown borer on August 10. They averaged 2.6 runner plants per plant as compared with 3 runner plants in the uninfested checks.

Some writers state that crown-borer eggs are laid so early in the

season that runner plants are never infested. Evidence to the contrary was found in many western Kentucky berry patches. At Princeton, August 10, 1937, in cutting open plants from varietal test plots, 12 out of 736 runner plants were found infested by crown borer larvae. At Kevil, August 4, 1937, 7 out of 15 runner plants examined were infested with crown borer.

Prepupal Stage. A short prepupal stage of from 3 to 5 days precedes pupation. During this period the prepupa, which has a much whiter body than the active larva, does not feed and lies outstretched in the pupal cell (figure 4).

Pupation. The larva pupates within the strawberry crown, inside a cleared space in the larval burrow (figure 9).

As a rule, the head end of the

pupa is up but the pupae are often found in nearly horizontal cells. Judging from the fact that the first newly emerged adult found was cut from a strawberry plant on June 22, pupation began at Paducah about June 10, in 1937. Pupae were common in the field, both at Princeton and at Paducah, on June 22.

In 1938, on June 8, 210 infested berry plants were examined at



FIGURE 9. Crown borer pupa in borer-infested strawberry plant.

Princeton without finding a single prepupa or pupa. Six pupae with the eyes just turned dark, were cut from 178 infested plants, June 25. Based on the known length of the pupal stage, these individuals pupated about June 20. Judging by records of the first finding of adults, pupation began at Princeton about June 16, in 1938. At Lexington, the first pupa was found July 18, 1938, and it is estimated that pupation began there about July 10.

The length of the pupal stage during June, July, and the first part of August, 1937, varied from 8 to 11 days, with an average duration of 9.8 days for 20 pupae (see table 10).

Table 10. Duration of pupal stage of the strawberry crown borer, 1937.

Number	Date pupated	Date became adult	Number of days
1	6/27	7/7	10
2	6/29	7/9	10
3	7/1	7/11	10
4	7/1	7/10	9
5	7/1	7/11	10
6	7/7	7/15	8
7	7/7	7/16	9
8	7/7	7/16	9
9	7/9	7/18	9
10	7/14	7/23	9
11	7/14	7/24	10
12	7/14	7/24	10
13	7/14	7/24	10
14	7/17	7/27	10
15	7/17	7/28	11
16	7/21	7/31	10
17	7/21	8/1	11
18	7/21	8/1	11
19	7/21	8/1	11
20	7/28	8/7	10
20	Average		9.8

New-brood Adults. The earliest first-generation adult was found June 22, 1937, inside the crown of a strawberry plant brought from Paducah and heeled in at Princeton, under a small field cage. The first adult from Princeton material was reared June 27.

The newly emerged crown borer adult has a soft body and the first day has pure white elytra with a slightly brown thorax. Six or seven days are required for beetles to attain the adult color.

Newly emerged adults usually attain their full color within their pupal cells. There they may remain as long as ten or more days before chewing their way to the exterior of the crown. The exit holes of crown borer adults are found anywhere on the crowns from close to the surface of the soil to several inches below the surface. After emergence from the crowns, new adults burrow to the surface where they begin feeding on the leaves of the strawberry plants.

Table 11. Oviposition records of first-generation crown borers, 1937.

Egg cage number	Male became adult before	Female became adult before	Number of eggs laid	Oviposition period
37-140	6/28, Princeton	7/1, Paducah	4	7/26-8/5
37-14AA	7/13, Princeton	7/17, Princeton	8	8/19-9/14
37-14BB	7/17, Princeton	7/17, Princeton	0	
37-14CC	7/17, Princeton	7/17, Princeton	0	
37-14DD	7/17, Princeton	7/17, Princeton	7	8/17-9/13
37-14EE	7/17, Princeton	7/17, Princeton	0	
37-14FF	7/27, Princeton	7/27, Princeton	0	
37-14GG	7/27, Princeton	7/27, Princeton	0	
37-14HH	7/20, Princeton	7/20, Princeton	0	
37-14II	7/20, Princeton	7/20, Princeton	0	
37-14JJ	7/28, Princeton	7/28, Princeton	0	
37-14KK	7/28, Princeton	7/28, Princeton	0	

Number of Generations. Other workers with the strawberry crown borer, such as Marcovitch (1923) and Haseman and Sullivan (1927), report finding only a single generation a year. In 1937, the writer found good evidence of a small second generation in the course of rearing work carried on at Princeton. Twelve pairs of early, first-generation adults were isolated in jelly-glass egg cages and kept at outside temperatures. Three pairs of the earlier emerging adults mated and laid eggs (table 11). Judging by the dates at which these eggs were laid and actual rearing, there was still time for this second generation to be completed. The same procedure was carried out in 1938 at Lexington with early, first-generation adults sent from Princeton but no eggs were laid and no evidence for a second generation was secured that year.

PARASITES AND PREDATORS

The crown borer, like many other insects, is attacked by several insect parasites and predators. The larvae of a small wasp, identi-

fied by Dr. C. F. W. Muesebeck of the National Museum, as *Microbracon analcidis* Ashm. were found parasitizing several crown-borer larvae examined during the seasons of 1937 and 1938. The percent of parasitism was low, ranging from 2 to 4 percent. *M. analcidis* was reared from cocoons found in common cinquefoil (*P. canadensis*) and the cultivated strawberry. The larva of *Microbracon analcidis* is quite active and feeds externally on its host. When full grown it constructs a brownish cocoon to which the head capsule of the dead crown borer larva is attached.

Among the predators of the crown borer is the larva of a small histerid beetle⁴, one of which was found at Princeton, in the act of consuming a large crown borer in its burrow. The histerid pupated in an oval cocoon July 14 and emerged July 24, 1937.

During the summer of 1937 at Princeton, approximately ten wireworm larvae were found feeding on larvae or pupae of the strawberry crown borer. Two of these were reared and identified as *Monocrepidius auritus* Herbst⁵.

STATUS OF TYLODERMA FOVEOLATA (SAY)

Tyloderma foveolata, a species closely related to the strawberry crown borer, is commonly found in western Kentucky berry patches (figure 10). The host in which it breeds is *Oenothera lacinata* Hill⁶, the cut-leaved primrose, a plant which occurs in waste land or weedy berry patches.

Adults of *T. foveolata* have been found, occasionally, feeding on ripe strawberries close to a primrose plant. However, this insect has never been found breeding in the strawberry and certainly cannot be classed as a strawberry pest.



FIGURE 10. Adult of *Tyloderma foveolata*, close relative of strawberry crown borer.

⁴ Identified by H. S. Barber of the U. S. Bureau of Entomology, as *Hister americanus* Payk.

⁵ Reared and identified by H. H. Jewett of this Station.

⁶ Identified by Mary Didlake of this Station.

It is interesting to note that although *T. fragariae* and *T. foveolata* belong to the same genus, *foveolata* has fully developed hind wings while *fragariae* has not.

CONTROL MEASURES

Safe Distance for New Plantings. Adult crown borers cannot fly because their hind wings are vestigial. This means that the adults, unless carried by water, the berry grower, or some other agency, must reach new breeding grounds by crawling. How far borer adults can crawl in the absence of food plants has an important bearing on how far new plantings must be placed from old berry patches and other breeding places to avoid infestation. Various writers have hazarded guesses that new patches must be set at distances varying from 100 yards to half a mile. The writer tried to find out how far crown borer beetles can travel without food by actually marking beetles and releasing them at different distances from a patch of strawberries. A search for marked beetles was then made in the strawberry patch, in the rows at the end nearest the point of release.

In all, 1,038 adult crown borers were released in the course of the marking experiment which was made on the substation grounds at Princeton. The beetles were collected in an abandoned, heavily infested berry patch near Kevil. At Princeton, each beetle was spotted on its elytra with a quick-drying lacquer of the desired color, applied with a small camel's-hair brush. After drying, the beetles of each color were released at different distances from the strawberry patch.

Twenty-eight marked beetles were recovered (table 12). Seven adults were recovered of 160 liberated at a distance of 125 yards. One adult of 612 released at a point 300 yards away was recovered in the berry patch. Based on random distribution, it would be expected that the closer the beetles were released to the berry patch, the more beetles would reach it. The figures for the beetles recovered bear out this assumption.

Twenty-five of the 28 marked borers recovered were males. This was probably because most of the beetles released were males. At the time of day when beetles were originally collected and again when recovery collections were attempted, males were taken oftener

than females since females were often engaged in egg laying and thus were better concealed about the plants.

It was found further that adult crown borers can live at least 16 to 19 days when deprived of food but given moisture. This, coupled with the fact that in the marking experiment one adult traveled at least 125 yards in less than three days, gives some idea of how far a crown borer adult might crawl, even in the absence of food plants. Evidently, crown borer adults make much better use of their legs than was thought formerly.

Table 12. Summary of marking experiments to determine how far adult crown borers can travel to new patches without food, Princeton, 1937.

Number adults released	Distance from patch	Date released	Number recovered		Date of recovery
			Males	Females	
50	25 yards	April 15	8	0	2-May 4 1-May 11 3-May 12 1-May 19 1-May 20
50	50 yards	April 15	2	0	1-May 4 1-May 11
116	50 yards	June 3	6	1	3-June 11 2-July 13 2-July 18
50	68 yards	April 19	3	0	2-May 4 1-June 4
160	125 yards	May 8	5	2	1-May 11 3-May 20 3-June 4
612	300 yards	May 20	1	0	1-June 10
1038			25	3	

It is concluded from the marking experiment, that where no wild hosts are a factor, a new berry patch should be set at least 350 yards from any infested point. If this distance is impossible, then the farther away the better. Even a hundred-yard distance from a source of infestation will prevent many beetles from finding the new planting.

Crown-borer Barriers. In McCracken county, some berry growers will find it difficult to set their new patches at safe distances from sources of crown borer since so many farmers are producing berries and because borer-infested cinquefoil is very abundant.

Because adult crown borers cannot fly, an attempt was made to devise a barrier which the beetles could not cross. Tests were made with several barriers and one was developed (figure 11) of wood and galvanized iron which was practically beetle proof. The



FIGURE 11. Upper. Three barriers erected at Princeton, 1937-38. Lower. Close-up of barrier to show details of construction.

word "practically" is used since in 40 days of testing this barrier with 78 adults, one crossed the barrier.

Two barriers, size 30 x 50 feet, were constructed in November, 1937, and set up in an area recently plowed from the center of a heavily borer infested berry patch on the western Kentucky experiment substation farm at Princeton. The site of barrier No. 1 was

burned over previous to the plowing. A third barrier was built and set up March 11, 1938, in the same plowed area. Cleaned plants, dug February 18, 1938, were set inside these barriers late in March.

An attempt was made to keep down all vegetation close to the outer edge of the barriers and the barriers were inspected at intervals for breaks in the joints and washing away of dirt along the lower edges.

It was found difficult to prevent occasional weeds from growing against the barriers and there was some buckling and spreading of the wooden sections due to temperature changes. Too, heavy rains flooded them several times and washed away the dirt along the lower sides. All these things allowed a few crown borers to get inside the barriers and infest the plants growing there.

The mother plants remaining inside the three barriers were cut open August 10 and 11, 1938, and their infestation noted (table 13). All barriers contained some crown borers. The percent of infested mother plants in the three were 31, 66, and 20, respectively. The barrier containing the smallest infestation was built in the spring of 1938 and was subject to the least buckling and washing. All barriers, evidently, repelled many crown borer adults since unguarded plants set in similar situations in 1937 were 88.8 percent infested by August 10.

Table 13. Extent of crown-borer infestation in mother plants in Princeton barrier plots, August 10, 11, 1938.

Row	Barrier 1		Barrier 2		Barrier 3	
	Uninfested	Infested	Uninfested	Infested	Uninfested	Infested
1	23	9	12	10	16	13
2	17	8	6	18	21	3
3	20	7	9	16	21	2
4	17	9	8	18	20	4
5	17	11	8	15	19	5
6	16	6	7	20	22	2
TOTALS	110	50	50	97	119	29
Percent		31		66		20

As a result of these tests, barriers are regarded as impractical. They are expensive, hard to construct and hard to maintain. In addition, they raise problems of getting work animals in and out

of fields and may injure stock if they get a foot under the sharp outer edge.

Barriers like those tested might be used to advantage in experimental or demonstration work with crown borer. By using them, plots with and without crown borer could be run side by side.

When to Dig Plants. In western Kentucky, plants for setting new berry patches should be dug between December 1 and March 1. Judging from counts made by H. Garman in 1921, of Bowling Green material, and by the writer in 1937 and 1938, of Princeton material, only in rare cases will crown borers in any stage be found in infested berry plants after December 1 (table 14). March 1 is set as the deadline for digging plants in the spring. As explained before, in 1937 and 1938, no crown borer eggs were laid before early March.

Table 14. Occurrence of crown borer in injured plants in the field.

Locality and date	Number of injured plants	Number of larvae and prepupae	Number of pupae	Number of adults
Bowling Green				
Aug. 8, 1921	208	38	10	14
Sept. 6, 1921	152	56	23	14
Oct. 22, 1921	72	4	17	13
Dec. 6, 1921	70	0	0	0
Princeton				
Aug. 9-11, 1937	207	Many	26	14
Oct. 21, 1937	115	0	1*	0
Nov. 17, 1937	121	0	0	0
Dec. 24, 1937	117	0	0	1
Aug. 10-11, 1938	122	60	14	16
Sept. 15, 1938	146	24	12	4
Oct. 14, 1938	181	1	3	9
Nov. 15-17, 1938	261	0	0	1
Lexington				
Oct. 15, 1937	17	0	2	3

* Became adult November 1, 1937.

Plants should be cleaned in the patch where they are dug, to avoid scattering the crown borer beetles. In cleaning, most of the dirt must be shaken off, all trash removed, and all dead leaves, runners and leaf bases pulled off. This leaves a plant with one or two green leaves and no dead ones. Plants with multiple crowns

should be separated and any old, dead, crown bases should be broken off.

Cleaning as described above gets rid of most of the adult crown borers hibernating in the soil or in trash about the plants. Careful washing in a pond, large tank or barrel of water will remove the rest. Any crown borer adults float to the surface and may be skimmed off.

If the grower does not wish to set his patch at the time his plants are dug and cleaned, he should heel in the cleaned plants in a safe place (350 yards from source of infestation). In proper heeling in, a furrow is opened and the plants are laid singly against one side, with the roots well spread. The furrow is then closed and the dirt packed against each plant.

Selecting Plants. One-year-old plants, formed before August 15 of the preceding year, should be selected for setting new patches. Runner plants, even in heavily infested patches, are usually only lightly infested and so will prove more thrifty. In addition, tests have shown that the most berries are produced by early set, one-year-old plants.

It is possible for growers to take plants from heavily infested berry patches and free them of crown borer as described above. However, the surest way for a grower to start a borer-free patch is to use only certified plants from inspected patches. Even when using such plants, well-cleaned, early dug plants are preferred.

Where to Plant Strawberries. It is best to set berries only on land that has been previously cultivated for one or more years. This is to avoid setting where infested wild hosts may have grown recently. In western Kentucky infested cinquefoil often flourishes in waste land and in wild-grass pastures. Many growers feel that tobacco is a good crop to follow with strawberries and plan their rotation accordingly.

Usually it is not safe to plant new strawberry patches on or near ground which was in berries the previous year. Many growers when plowing up an old patch leave plants around which crown borer adults congregate. Too, the writer has visited farms where berry growers, in plowing, overlooked whole rows of plants hidden in the weeds.

Treatment of Old Beds. It is a common practice in western Kentucky to pick a berry patch until it runs out. The patch is then abandoned and left unplowed for as long as five or six years. In McCracken county, farms were visited where as many as three, old, worthless patches were found adjacent to the new berry-growing area. These old, idle berry beds are ideal for breeding tremendous numbers of crown borers, and the writer believes that neglected patches are one of the main causes for the crown borer troubles of western Kentucky.

All old beds should be plowed just as soon as the last crate of berries is harvested. After plowing, the ground should be disked, dragged once or twice and sown down. Often disking before plowing is found helpful. Fall and early spring are poor times to plow up old patches. It is almost impossible to get rid of all the plants and crown borer continues breeding on the few that are left. Just disking an old patch as is commonly done in western Kentucky is time wasted.

By experiment it was found that crown borer beetles can dig their way to the surface thru several inches of soil. If no plants are left for them to feed on they soon starve. Burning over old patches before plowing, if done thoroly, kills all stages of the crown borer.

Insecticides. Control of the strawberry crown borer with poison sprays or dusts does not appear very promising. In the first place, where a patch is close to a source of infestation, crown borer beetles keep moving in over an extended period of time. In the second place, crown borer adults are very quick to detect poison and will feed but sparingly, if at all, on poisoned foliage. They also appear to be very resistant to ordinary poisons.

In March, 1938, when adults were feeding actively on exposed foliage in the field, some small-scale tests were made with lead arsenate, with 1 part to 10 parts of hydrated lime, and with barium fluosilicate dust. By the sixth day, 5 out of 16 adults were killed by the barium fluosilicate and 1 out of 15 by the lead arsenate. It was noted that only half as many feeding holes were made by the beetles confined with dusted foliage as were made by beetles with undusted foliage. In addition, of the 33 feeding holes which beetles made on dusted plants 16 were located on the sides of the leaf petioles

and elsewhere where there was little or no poison. Sweetened dusts were also tried in the laboratory but without success.

Destruction of Wild Hosts. Cinquefoil infested with crown borer is found on many western Kentucky farms. In many cases, berry growers could get rid of this source of crown borer by cleaning up a fence row or a ditch or two, once they have learned to recognize it. Digging up and burning the cinquefoil, crowns and all, is the best way to get rid of it.

SUMMARY

The strawberry crown borer, *Tyloderma fragariae* (Riley), has been a serious pest of strawberries in western Kentucky for the past forty years. In this state, in addition to the cultivated strawberry, crown borer was found breeding in common cinquefoil and the wild strawberry. Common cinquefoil is abundant and often is the source of crown-borer infestation for nearby berry patches. Other investigators have reported that the crown borer has a single generation a year. In 1937, a small second generation was reared at Princeton, Kentucky.

The strawberry crown borer usually passes the winter in the adult stage under trash or in the soil. A very few crown borers pass the winter within infested plants and mature in February and March. It is concluded that no crown borer eggs are laid until early March. It is also concluded that the simplest way to secure data on early egg-laying is to follow egg development by dissection of a sufficient number of females and correlate this with air temperatures. Egg laying continues from March until September. Eleven females laid an average of 62.7 eggs each during 1937. Some female crown borers laid eggs a second year. Total maximum egg production for a female which laid during the seasons of 1937 and 1938 was 142. Crown-borer eggs are always laid in the strawberry plant. They are usually deposited in excavations made in the crown or old leaf bases slightly above the origin of the lateral roots and close to the soil surface.

Plants attacked by crown-borer larvae are killed, stunted, or may show no other effects except a reduction in number of runners and runner plants. In dry years, entire fields are often wiped out by brown borer. Pupation of borer larvae began between June 10

and June 16 in 1937 and 1938 in western Kentucky. First-generation adults began emerging late in June. One parasite, *Microbracon analcidis* Ashm. and two predators, *Monocrepidius auritus* Herbst and *Hister americanus* Payk. were found attacking the crown borer. *Tyloderma foveolata* (Say), a close relative of the crown borer, was common in strawberry patches. It breeds in *Oenothera laciniata* Hill and is not a strawberry pest.

Insecticides and barriers were tried as means of crown-borer control. Results of the tests do not warrant their recommendation.

Certain recommendations for crown-borer control are made as a result of this investigation.

1. *New strawberry patches should be set at least 350 yards from a source of infestation.* Field tests with 1,038 marked crown borer adults showed that the beetles can crawl 300 yards without a source of food.

2. *Plants for new patches should be dug between December 1 and March 1.* Plants dug after December 1 rarely contain crown borer larvae, pupae, or adults, and when dug before March 1, will contain no eggs. Plants dug too early for setting should be heeled in at a distance of 350 yards from a source of infestation.

3. *Certified plants are preferred for setting new patches.* Plants from infested patches can be used for starting borer-free patches provided they are dug before March 1 and properly cleaned and washed to get rid of adhering adults. Plants from patches found to be free of crown borer are preferred. Even certified plants should be dug early and cleaned.

4. *Set strawberry patches only on land in cultivation for one or more years.*

5. *Destroy all berry patches after the second year of picking.*

6. *Destroy the common wild host of the crown borer, common cinquefoil.*

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